Questions and Answers

Space Technology Research Vehicle-2 (STRV-2)

Q1. *What BMDO Experiments are on STRV-2 and what is their purpose*

STRV-2 provides the Ballistic Missile Defense Organization (BMDO) a low cost orbital testbed to demonstrate a number of advanced space technologies. The BMDO experiment suite includes: (1) a laser communications system, (2) an advanced Vibration, Isolation, Suppression and Steering (VISS) system, (3) Space Active Modular Materials Experiments (SAMMES), (4) an Electronics Test Bed (ETB), (5) a Mid-Wavelength Infrared (MWIR) Experiment, and (6) an All Composite Experimental Spacecraft Structure (ACESS).

High-bandwidth laser communication transmission has been demonstrated in ground-based and space-to-space experiments. The Laser Communications Experiment, developed by BMDO, will be the first space-to-ground demonstration of high bandwidth, high rate data transmission. Laser communication systems operating at optical frequencies are compact, lightweight, and have the potential for providing very high bandwidth data transmission to ground or airborne platform receivers. Space-based surveillance produces large amounts of data that must be processed in real time to be of value to the ballistic missile battle management commands. The STRV-2 laser communications experiment will provide a demonstration that high-speed data links can be made between orbiting spacecraft and ground/airborne platform transceivers.

The MWIR experiment was developed by the United Kingdom Ministry of Defence, at no cost to the US Government, in a collaborative arrangement with BMDO. It incorporates optical elements that will provide data in wavelength regions to be used in future space-based surveillance systems.

Space-based optical detection systems must be mounted on stable platforms with low levels of mechanical jitter. "Noisy" systems result in image blur and loss of detection capability. An advanced vibration, isolation, suppression, and steering (VISS) system will demonstrate adaptive structures technology that will significantly reduce structure vibration to levels providing near blur-free images. In addition, this technology can enable the use of lower cost, non-precision spacecraft in place of precision optical systems. The techniques to be evaluated on the STRV-2 platform use low-cost technologies readily adaptable to a variety of system needs. Future commercial and military systems will benefit from demonstration of these technologies for space-based optical systems.

The Space Active Modular Materials Experiments (SAMMES) incorporates advanced, extremely sensitive sensors that monitor the properties of critical satellite materials and subsystem components in the severe space radiation and corrosive low earth orbit environments. In addition, the SAMMES hardware (a) measures radiation levels encountered at the higher mission altitudes, (b) provides critical experiment control functions, and (c) supports the major experiment systems on the STRV-2 module.

The Electronics Test Bed (ETB) enables demonstrating the durability of advanced micro-electronic components and “Commercial Off-The Shelf (COTS)” devices in the space environment. Use of COTS Products is becoming increasingly important in design of advanced electronic systems, such as on-board data processors and memory storage systems. The fluence of micro-meteorites and debris at altitudes where the effects of atmospheric drag are too small to provide the "debris cleansing” will be monitored by sensors on the ETB. Experiments have been provided by the NASA Langley Research Center and BMDO's Small Business Innovative Research (SBIR) program. The Electronic Test Bed (ETB) provides system designers with an opportunity to test device designs proposed for incorporation in future space systems.

Composite structure technology can enable significant reductions in weight and cost while maintaining stiffness and strength for selected spacecraft structural components. The All Composite Experimental Spacecraft Structure (ACESS) will validate the use of composite structures for precision spacecraft optical systems.

Q2. What is the objective for the UK experiment?

The UK will acquire data to evaluate the capability of MWIR sensor systems to detect non-afterburning aircraft from space using passive detection. Measurements will be made to determine the detectable limits for a variety of backgrounds (ocean, urban, rural). A secondary objective of the MWIR experiment is to collect earth background data as a function of seasonal variation. This data is needed for effective ballistic missile detection.

Q3. *How does the vibration suppression system work?*

The Honeywell Corporation designed and fabricated a system that uses six active damping struts and an electronics package with accelerometers and gap sensors to measure and reduce motion induced by mechanical disturbances. Signals from the accelerometers and gap sensors are processed using control algorithms developed by the Jet Propulsion Laboratory. Drive signals for voice coil transducers are generated and activation of the active damping struts produce forces to negate motion caused by platform mechanical noise. Isolation is achieved through the use of passive damping in the struts and algorithms providing active control with acceleration feedback from payload-mounted accelerometers. In the suppression mode, acceleration and cryocooler control signal feedback are used. Steering is accomplished with closed-loop control also using payload accelerometers. The simultaneous isolation, suppression, and steering mode is possible because of the differences in frequency of the various disturbances.

Q4. *Can you provide more information on the materials degradation experiments to be performed during the STRV-2?*

All materials, mechanical assemblies, and electronic devices, whether used in spacecraft or terrestrial applications, degrade over time. Replacing or repairing satellite components is extremely costly and is rarely done. It is therefore imperative for satellite designers to know how a given material, assembly or device degrades in the harsh space environment.

The SAMMES is monitoring the characteristics of an important group of materials known as thermal control coatings. These materials, including paints and polymer films, are used by satellite designers to control the temperature of a spacecraft. Designers can passively control the temperature of a satellite by using combinations of thermal control coatings. Over time some of these materials will age resulting in changes in their absorption and reflection characteristics as a result of the harsh space environment. SAMMES will provide the data needed to evaluate how the solar absorption and reflection properties of these advanced thermal control coatings change. From this data, designers will be able to select the types and thicknesses for these coatings to ensure that the temperature of the satellite remains within acceptable temperature limits over its entire lifetime. Furthermore, as systems are developed for autonomous spacecraft, the satellite itself will use this information to adjust its operating profile similar to the way modern automobiles do as they continually adjust their performance using computer based engine monitoring systems.

Q5. *Hasn't this been done before?*

The selection of materials available to satellite designers changes as improvements are made to previously available materials. Samples to be tested during the STRV-2 mission have been provided by private industry, as representative of materials that may provide improved thermal control performance. Space data on these specific materials is either not available or is not adequate for design decisions.

Q6. *Can you describe the contamination experiments to be performed during STRV-2 Mission?*

In addition to monitoring material degradation, SAMMES also provides for active monitoring of satellite contamination. Satellites, particularly their electronic devices and wiring, are made from a range of materials including a variety of plastics, glues, paints, and sealants. Each of these emits hydrocarbons and other gaseous molecules, especially when placed in the "vacuum" of space. This process is called "outgassing." In a spacecraft, these "outgassing" products can flow through the satellite and deposit (condense) on cold surfaces such as the mirrors or optical lenses of a sensor system. When this occurs, the clarity of the imagery obtained by the sensor can be degraded. The STRV-2 structure uses an advanced, all composite material which is expected to provide the benefits of a low cost, light weight structure with low outgassing and contaminant production. The SAMMES sensors on STRV-2 will verify, through direct measurement, the contamination produced by this composite structure.

The SAMMES contamination sensors will use two methods for determining the amount and rate of deposition of "outgassed" contaminants around this satellite. Special devices, called Quartz Crystal Microbalances (QCMs), capable of measuring contamination films as thin as 0.0000002 inches thick, will be used to monitor contamination at select locations on the spacecraft.

The second method relies on the thermal behavior of small highly polished mirror surfaces. By measuring the rate of temperature change of these mirrors as they pass in and out of sunlight scientists can determine the contamination build-up on the surface. These data, combined with the measurements from the QCMs will allow scientists to determine how these "outgassing products" flow around the spacecraft and the rate at which they deposit on critical surfaces.

Q7. *Given the secrecy surrounding some BMDO programs, why is the overall STRV-2 unclassified?*

The BMDO STRV-2 experiments do not test missile defense designs that require a national security classification. The flight hardware and the experiment telemetry are unclassified.

Q8. *Will the results of the BMDO STRV-2 experiments be made available to the public?*

All the data obtained from the BMDO STRV-2 experiments applicable to the design and operation of civilian and commercial spacecraft will be made available to scientific investigators for analysis and interpretation. BMDO maintains an active technology transfer office in support of the government policy to transfer DoD technology to the civilian and commercial sectors. In addition, reports on results of these experiments will be published in the open literature and included in the Defense Logistics Agency's technology transfer database.

Q9. *What exactly are the benefits of the new technologies being demonstrated?*

The MWIR background/clutter data will provide missile designers information necessary to develop effective detection/tracking algorithms. Demonstration of adaptive structures technology for vibration suppression and cancellation will provide designers of precision space instruments greater flexibility in matching design requirements with characteristics of non-precision spacecraft with potential cost savings. Demonstration of successful transmission of high bandwidth data using the laser communications space-ground link will offer satellite designers compact, light weight alternatives to traditional RF data links. As the mass of data acquired by space systems increases in both civil and military systems, this becomes increasingly important. The SAMMES materials degradation and contamination monitoring system will extend our knowledge base on the behavior of new materials exposed to the space environment and provide a path to the development of future miniaturized systems for autonomous satellites. These data are crucial for evaluating the lifetime of orbital systems. Measurement of the radiation and micro-meteorite/debris environment at Mid Earth Orbit altitudes will provide an understanding of factors essential to determine the useful life of satellites operating in these environments. Demonstration of light weight, low cost composite satellite structures will result in designs that can lead to cost reductions up to 30% compared to traditional materials. Again, the military, civilian, and commercial satellite industries will benefit from the knowledge acquired from these experiments.

Q10. *Will these new technologies be incorporated into other BMDO programs?*

Successful completion of the BMDO STRV-2 experiments will assist in the insertion of these advanced technologies into BMDO, other military, commercial, and civilian programs.

Q11. *Given the redirection of BMDO to ground-based defenses, why is BMDO continuing to test new spacecraft technologies?*

Surveillance, detection and tracking of potential targets are essential elements for all ground-based defense systems. Space-based systems such as the Defense Satellite Program, Space Missile Tracking System, and Alert Locate And Report Missiles play a critical role in maximizing the effectiveness of deployed defensive systems. Consequently, the BMDO has a continuing interest in the development and demonstration of technologies that will enhance the performance of such space-based surveillance systems. Technologies such as adaptive structures used for vibration suppression can also be used to improve ground based interceptor performance. Data from space tests provides an essential demonstration of their effectiveness in a system context.

Q12. *What other organizations are involved in STRV-2 and what are their roles?*

The United Kingdom Ministry of Defence (UK MOD) is the other major sponsor of STRV-2 experiment hardware. The Defence Evaluation and Research Agency (DERA) of the UK MOD is responsible for design, fabrication, test and on-orbit operation of the MWIR system. The US Air Force Phillips Laboratory is co-sponsor of the VISS and ACESS fabricated by Honeywell, Inc. and Boeing. Astro-Terra, Inc. fabricated the Laser Communications system. Physical Sciences, Inc. provided the SAMMES hardware. NASA Langley Research Center is provided one of the micro-meteorite/debris experiments; IIT, Corning NY provided the other. Texas Instruments, Inc. provided the tactical cryocoolers used in the MWIR system. Loral provided the IMU. The Jet Propulsion Laboratory integrated and tested the experiments into the STRV-2 module. The International Cooperative Programs Office in DoD, administrator of the Nunn-Warner program funding, has provided essential supplementary funding for the STRV-2 program.

Q13. *How long has BMDO been working on these experiments, and what is their cost?*

The Laser Communications Experiment is based on work five years of effort funded by BMDO's Innovative Science and Technology. The SAMMES experiment is a follow-on to an earlier SAMMES experiment lost in the failure of STEP Mission 3. The VISS, ETB, and all-composite bus experiments were developed as part of the STRV-2 program concept initiated in 1994. Total BMDO experiment cost is estimated to be $18.1M.